EFFECTS OF METHODS OF FERTILIZER PLACEMENT ON FINE BEANS (PHASELOUS VULGARIS L) GROWTH AND NUTRIENT DISTRIBUTION IN THE SOIL.

BY

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DEDICATION

To my Parents, Brothers and Sisters for their support and patience during my long stay at UNZA. I have to single out my Father's financial support and encouragement, without which, I would not have come this far.

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ABSTRACT

This study was carried out at Natural Resources Development College-Zambia Export Grower's Association (NZTT), to determine the effects of three methods of fertilizer placement on fine beans growth and nutrient distribution during the 2001/2002 growing season. The three treatments that were evaluated and replicated four times in a randomized complete block design were band placement of fertilizer 7 cm from the seed row, broadcasting of fertilizer between the seed rows and placement of fertilizer 5 cm below the seed row. The fertilizer WVC (Wheat, Vegetables and Cotton) was applied at a rate of 175 kg/ha to provide 14 kg/ha N, 18 kg/ha P and 23 kg/ha K. The plant parameters observed were the leaf area per plant, plant height and root depth.

Fine beans grown on plots where fertilizer was placed within seed row generally had higher mean values of leaf area, plant height and root depth than the other two treatments, although in most cases there were not always statistically significantly different from the plants grown on plots where the other two fertilizer application methods were used.

To determine the nutrient distribution, soil samples were taken from 0-15 cm, 15-30 cm and 30-45 cm depths before planting and in the third, fifth, eighth and tenth week after planting. The electrical conductivity and the contents of phosphorus, nitrate nitrogen and ammonium nitrogen were determined in the soil samples were measured. No specific pattern was observed in the distribution of phosphorus and ammonium nitrogen. The concentration of nitrate nitrogen and the reading of the electrical conductivity, were higher in the fertilizer next to the seed row than, the fertilizer broadcast and the fertilizer within seed row. In all the treatments, the highest readings of the nutrients and the electrical conductivity were in the top 0-15 cm depth, while the lowest values were mostly observed in the 30-45 cm soil depth in most cases. There were no significant differences in the distribution of phosphorus. However, there were statistically significant differences in the distribution of nitrate nitrogen in the fifth week within both the 0-15 cm and the 30-45 cm soil depth. With ammonium nitrogen, there were statistically significant differences in the tenth week within the 30-45 cm depth. Statistically, there were

significant differences in the case of the electrical conductivity in the eighth week within the 0-15 cm soil depth and in the tenth week within the 15-30 cm as well as within the 30-45 cm.

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1.0 INTRODUCTION

Improper placement of fertilizer can result in poor distribution of the nutrients leading to its lack of maximum utilization by the plant. This may occur due to leaching and fixation of the nutrients in the soil. Fertilizers are an essential and major input for fine beans, which is grown for both the local and export market. In order to maximize utilization of the fertilizer and increase profits, it is important to know which placement method contributes the most to fine beans growth.

A number of fertilizer placement methods are used. The major factors that determine the method to use include, the crop characteristics, soil characteristics, the moisture supply, yield goal and the cost of the fertilizer in relation to the sale price of the crop (Tisdale and et al 1985)

Fertilizer can be broadcast, which is the uniform spreading of the fertilizer over the field. This method gives good results for row crops and crops that are broadcast sown. The fertilizer is broadcast after the land has been ploughed and it is mixed into the soil with cultivating implements (Olaitan and et al 1984). Fertilizer can also be banded, which involves placing the fertilizer slightly below and to one side of the seed. However, the fertilizer should not be placed too close to the seed, otherwise injury by salt burn may occur, when it sprouts (Donahue and et al 1983)

When the fertilizer is applied, the nutrients become soluble in water and react with the soil, becoming unavailable or leaching out of the root zone. In the case of nitrate nitrogen, it is prone to leaching since it is soluble in water and mobile. Phosphorus is very immobile in soils and tends to react with other ions in soil solution to form insoluble unavailable compounds (Forth, 1984)

Currently, farms growing fine beans are using a number of fertilizer placement methods. Some farms are using the banding method, while others are using the broadcasting method. A number of other farms place the fertilizer in the centre of the bed. With so many methods of fertilizer placement, it is not clear what the effects are on fine beans growth, as well as on nutrient distribution in the soil. Since the methods of fertilizer placement are different, the following hypothesis can be made:

1. The growth of fine beans in terms of leaf area, plant height and root depth will be different in relation to the different methods of fertilizer placement.

2. The distribution of the nutrients in particular phosphorus, nitrate and ammonium nitrogen will be different in relation to the different methods of fertilizer placement.

Not a lot of research has been done and documented on fertilizer placement methods for fine beans and nutrient distribution under fine beans. Therefore the objectives of the study were as follows:

1. To determine the effects of different methods of fertilizer placement on fine beans growth in terms of leaf area, plant height and root depth.
2. To determine the effects of different fertilizer placement methods on distribution of phosphorus, nitrate nitrogen and ammonium nitrogen.

2.0 LITERATURE REVIEW

2.1 Fertilizer placement methods

According to Harmsen and Kolebrander (1965), nitrogen fertilizer can be band placed to be quickly reached by roots soon after germination, yet should be far enough away from the seed to avoid salt damage. They also suggest that availability of nitrogen applied on the surface is largely dependent on rain or irrigation water to move the nitrogen into the root zone.

With phosphorus, studies by Philip and Webb (1971) indicate that larger proportions of the fertilizer may be banded near the row at planting time on soils with large phosphorus fixing capacities in an attempt to minimize contact with the soil and maintain availability of the fertilizer P. According to Philips and Webb (1971), phosphorus can be broadcast on the surface and plowed under on soils of low or moderate fixing capacities. This method mixes the fertilizer within the plow layer and places at least part of it deep enough in the soil for it to be in a moist zone, the greater part of the zone.

2.2 Nutrient distribution

According to White (1997) nitrogen in the form of nitrate is very vulnerable to leaching. It is therefore concentrated mainly in the surface 20-25cm of soil, where it is produced as an end product of mineralization of organic N or from fertilizers. White (1997) also shows that the leaching is mainly influenced by the soil structure and texture. On sandy soils, studies have shown that nitrate is lost rapidly by leaching when rainfall exceeds evaporation. In a soil with water content of 0.2 m^3m^{-3} at field capacity, 100mm of rainfall can displace nitrate downwards to a depth of 500mm. For clay soil, with water content of 0.4 m^3m^{-3} at field capacity, 100mm of rainfall is expected to displace nitrate to a depth of 250mm by miscible displacement.

Work by Harmsen and Kolenbrander (1965), showed that the vertical downward displacement of nitrogen in sandy soils, beginning with moisture content around field capacity was about 45cm per 100mm rainfall entering the surface, about 30cm in soils with 20-40% of the particles less than 20 microns in diameter and only about 20cm displacement per 100mm of rainfall for heavy clay soils.

The amount of moisture also affects the nitrate distribution in the soil. According to Tisdale (1985) under conditions of excessive precipitation or irrigation, it is leached out of the upper horizons of the soil. During extremely dry weather, however and when capillary movement of the water is possible, there is upward movement of nitrate with the upward movement of water. Under such conditions, nitrates tend to accumulate in the upper horizons of the soil or even on the soil surface.

Bauder and Montgomery (1979) as cited by Tisdale in their studies found that approximately 45 to 55% of the nitrogen applied as ammonium sulphate and urea was recovered as nitrate (NO_3) in the 0-30cm depths. This was on a soil that had received 107mm of precipitation.

Results of studies by Leyshan and Kilcher (1976) cited by Tisdale showed that nitrate nitrogen in the treated soils with low fertilizer rates had virtually no effect. However, at the higher rates, nitrate nitrogen increased dramatically and was mainly concentrated at depths of 60-90cm. Considerable amounts of NO_3-N also occurred in the 30-60cm.

For phosphorus, studies have shown that little of it is lost by leaching. The phosphorus added as fertilizers therefore tends to accumulate in the surface horizon of soils used for production of highly fertilized crops like potatoes, vegetables and citrus (Tisdale 1985)

According to Thomas and et al (1967), when soils are fertilized, the soil solution concentration of phosphorus will be raised as much as 10 times. In sandy soils and in reduced muck soils, phosphorus can move in fairly large quantities, probably as dicalcium phosphate. This is a good possibility in soils with few oxides of aluminum or iron.

2.3 Effects of different methods of fertilizer placement on fine beans

There is little in formation available in this area. However, according to Cooke (1982) higher yields are obtained by placing phosphorus- potassium compound fertilizer 5cm to the side of the seed and 7.5cm below the soil surface. Previous results of trials have shown that placing 350kg/ha of fertilizer gave higher yields than broadcasting twice as much when winter and spring beans were grown (Cooke 1982)

Smith and et al (1981-83) carried out research to compare the effects of fertilizer placement on growth responses of snap beans. Their results showed that vine weights were higher in the banded treatments with both single and double nitrogen-phosphorus increments when compared to broadcast treatments. However, the pod yield differences were inconsistent. Pod yield and vine weights were higher in the double increment of banding and side dressing than any treatment.

3.0 MATERIALS AND METHODS

3.1 Site description

3.1.1 Location.

The experiment was conducted at the Natural Resources Development College (NRDC) - Zambia Export Grower's Association (ZEGA) Training Trust (NZTT) in Lusaka during the 2001/2002 growing season. The area is geographically located between longitudes 28°20′ and 28°25′ East and latitudes 15°20′and 15°25′ south, with an altitude of 1230m above sea level. The soil on which the studies were conducted is bright brown, with medium acidity and low available phosphorus. Using the United States Department of Agriculture textural class, the soil belongs to the clay class. Selected physical and chemical properties of the soil are given in table 1 below.

Table 1: Selected physical and chemical properties of the soil at the study site.

pH (0.01 M $CaCl_2$)	5.08
Available phosphorus (mg/kg)	3.5
Organic matter %	3.44
% Clay	42.4
% Sand	43.4
% Silt	14.4
% Wilting point (g H_2O/100g soil)	13
% Field capacity (g H_2O/100g soil)	27

The site is in Agro-Ecological Zone 2 of Zambia and has a tropical continental climate. The zone generally has an elevation of between 900 and 1300 metres, with a growing season that ranges between 100 and 140 days (Bunyolo 1995). There are three main distinct seasons, a wet season from November to April, a cold dry season from May to July and a hot dry season from August to October. A few of the climatic parameters of the area are given in Table 2.

Table 2: Climatic parameters of UNZA farm (nearby location to study site)

Annual mean rainfall (mm)	1028
Annual mean minimum temperature (^{0}c)	13.3
Annual mean maximum temperature (^{0}c)	25

Source: Chinene (1988)

3.1.2 History of the plot

The plot used previously had fine beans, which had been grown using irrigation. WVC (Wheat, Vegetables and Cotton) had been applied to provide 18 kg/ha of phosphorus, 23 kg/ha of potassium and 35 kg/ha of nitrogen. A fertigation program similar to the one applied in the studies was previously used. The composition of WVC fertilizer is shown in table 3.

Table 3: Composition of WVC (Wheat, vegetables and cotton) fertilizer

% N	% P_2O_5	% K_2O	% Zn	% S	% B
8	24	16	0.5	5	0.1

3.2 Management of the field

3.2.1 Land preparation and design

The land was disked and beds were made using the tractor. Experimental plots were 1 m wide and 5 m long, with inter plot spacing of 0.50 m. The design used was a randomized complete block design, which had three treatments and four replications. The three treatments that were evaluated include:

1. Treatment 1- WVC fertilizer placed 7 cm from the seed row.
2. Treatment 2- WVC fertilizer broadcast over the plot between the seed rows.
3. Treatment 3- WVC fertilizer placed 5 cm below the seed within seed row.

3.2.2 Planting and planting materials

The fine beans were planted on 18/12/01 with an inter row spacing of 45 cm and an intra row spacing of 5 cm. In treatment 1, the fertilizer was applied next to the seed row when planting at a distance of 7 cm from the seed row. In treatment 2, the fertilizer was broadcast and spread over the surface using a rake. In treatment 3, the fertilizer was applied within the seed row at a depth of 5 cm. In treatments 1 and 3, 67.5 g of WVC fertilizer, was applied in the seed row and next to the seed row respectively. In fertilizer broadcasting, 135 g of WVC fertilizer was applied between the seed rows.

3.3 Management of the vegetables.

3.3.1 Fertigation

Four weeks after planting, the fertigation program started with a combination of 25 kg of sulphate of potash and 25 kg of urea in which 10.63 kg of potassium and 11.5 kg of nitrogen was applied in 32 m^3 of water. During the seventh week, 25 kg of ammonium nitrate was applied (containing 8.63 kg nitrogen) in 47 m^3 water. In the eighth week a combination of 25 kg of potassium nitrate (containing 3.25 kg nitrogen and 9.56 kg potassium) and 25 kg of Calcium ammonium nitrate (containing 6.75 kg nitrogen) was applied in 26 m^3 of water.

3.3.2 Pest and disease management

Two days after planting, the herbicide Dual was applied to control the broad leaf weed. The fungicide Score and insecticide Decis were applied to control rust and caterpillars respectively. The other recommended fungicide and insecticide that were applied are Anvil to control rust and Karate to control caterpillars.

3.4 Monitoring of plant growth

During the growth of fine beans, a number of parameters were observed to monitor the growth. Parameters recorded were the root depth, plant height and leaf area. To get data on these parameters, five plants were taken from each row randomly in each plot.

To get the leaf area, the length and width of each leaf was measured and recorded. Plant height data was taken by measuring the height of the plant from the tip of the plant to the ground surface. In the case of root depth, the data was taken by measuring from the surface to the bottom of the root tip. This was a very tedious exercise and in the process, some roots got cut.

3.5 Soil sampling

To monitor the nutrient distribution, disturbed soil samples were taken from 0-15 cm, 15-30 cm and 30-45 cm. Successive soil samples were taken 20 cm away from the previous sampling point along the rows. The samples were collected 1 cm from the plants. Soil samples were collected before planting, three weeks after planting, five weeks after planting, seven and nine weeks after planting. The soil samples were taken using an auger and put in black plastic papers that had never been used before. Soil samples were stored in a cold room.

In the lab soil samples were air dried and crushed and passed through a 2mm sieve. The soil samples were then measured for electrical conductivity (EC) and analysis was done for phosphorus, ammonium and nitrate nitrogen. The methods for analysis are given below.

3.6 Methods of Lab Analysis

3.6.1 Nitrate and ammonium nitrogen

Five grams of soil was weighed and put in into a 250 ml conical flask and 50 ml of 2 M KCl solution was added. A stopper was put on the flask and the flask was put on the shaker for 30 minutes. The solution was then filtered.

To determine NH_4-N, 10 ml of the aliquot was taken using a pipette and put in a distillation flask. 0.10 g of MgO was added and the distillate was collected in a 100 ml flask containing 20 ml boric acid indicator solution. Titration was then carried out with 0.005 N H_2SO_4.

To determine NO_3-N, a spoonful Devarda alloy was added to the residue in the distillation flask and distillation was carried out once more. Nitrates were reduced to NH_4-N, distilled and determined by titration with H_2SO_4. A separate titration was carried out for both the NH_4-N and NO_3-N blank. The NH_4-N and NO_3-N was then calculated using the formula given below:

$$\text{mg/kg } NH_4\text{-N} = (\text{sample T - blank T})*35$$

$$\text{mg/kg } NO_3\text{-N} = (\text{sample T-blank T})*35$$

3.6.2 Electrical conductivity (soil to water extract)

Ten grams of air dry soil was weighed and transferred into a 100 ml plastic bottle to which 20 ml of distilled was added. A stopper was put on the bottle and shaking was done for an hour on a shaker. The conductivity meter was warmed up for about 20 minutes, followed by calibration of the meter using a solution of 0.01 M KCl.

3.6.3 Phosphorus determination

Three grams of air-dry soil was weighed and put in a 100 ml plastic bottle to which 21 ml of the bray 1 solution was added. The mixture was put on a shaker for a minute and the extract was then filtered using whatman No 42 filter paper. A pipette was used to take up 5 ml of the supernatant, which was transferred into a 25 ml volumetric flask. Distilled water of 10 ml was added to the supernatant, followed by addition of 4 ml of reagent B and made up to volume with distilled water.

The colour was allowed to develop for 15 minutes and the P content was determined on the spectrometer at a wavelength of 882 nm. A set of standard P- solutions was developed in particular 0.5 mg/L and 1.0 mg/L, including a blank. The concentration of phosphorus was calculated using the formula below:

$$mg/kg\ P = P\ ppm*35$$

3.7 Data analysis

The data was subjected to analysis of variance (ANOVA) to detect any difference among the treatment means. The least significant difference was used to separate the means at 0.05 level of significance.

4.0 RESULTS AND DISCUSSION

4.1 Plant parameters

4.1.1 Leaf area

The results of the mean leaf area per plant are given in figure 1. From figure 1, the results show that there was a gradual increase in the leaf area per plant from the third week to the seventh week. In the ninth week, there was a decrease in the leaf area per plant in comparison to the seventh week. The mean leaf area per plant was numerically higher in the fertilizer within seed row treatment compared to the fertilizer broadcast and fertilizer next to seed row treatments. The fertilizer broadcast treatment gave the second highest numerical mean leaf area per plant, while the fertilizer next to seed row treatment gave the lowest numerical mean leaf area per plant.

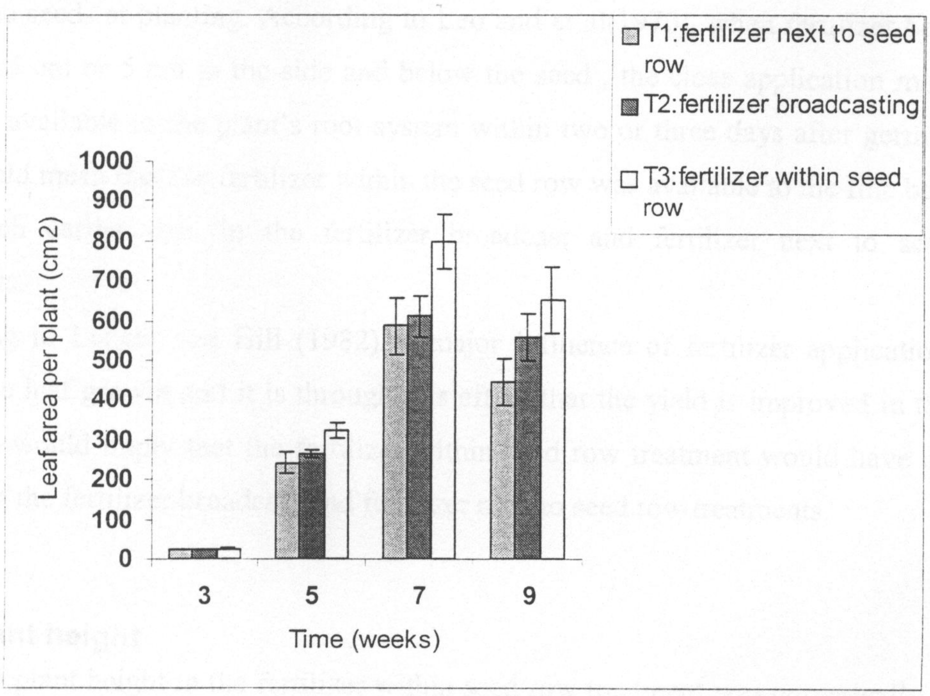

Figure 1: Leaf area per plant of fine beans at two-week intervals in relation to three methods of fertilizer placement

Statistically, there were no significant difference among the treatment means in the third, fifth and ninth weeks (Table 4). However, there was a significant difference in the seventh week. The fertilizer within seed row was significantly higher than the fertilizer broadcast and fertilizer next to seed row treatments. There was no significant difference between the fertilizer next to seed row and fertilizer broadcast treatments.

Table 4: Mean values of leaf area per plant of fine beans at two intervals.

Treatment	Week 3	Week 5	Week 7	Week 9
Fertilizer next to seed row	26.15	242.35	586.13a*	446.02
Fertilizer broadcast	26	266.05	610.47a	557.86
Fertilizer within seed row	26.76	324.76	796.64b	650.36

*Means followed by the same letter within the column are not significantly different at 0.05 level of significance.

The highest leaf area per plant was observed in the fertilizer within seed row treatment due to the fact that the tap roots were growing directly into the fertilizer that was placed below the seeds at planting. According to Leo and et al(1970), when fertilizer bands are placed 2.5 cm or 5 cm to the side and below the seed , the close application makes the fertilizer available to the plant's root system within two or three days after germination. This would mean that the fertilizer within the seed row was available to the fine beans tap root much earlier than in the fertilizer broadcast and fertilizer next to seed row treatments.

According to Langer and Hill (1982), a major influence of fertilizer application is to encourage leaf growth and it is through this effect that the yield is improved in the long run. This would imply that the fertilizer within seed row treatment would have a better yield than the fertilizer broadcast and fertilizer next to seed row treatments.

4.1.2 Plant height

The mean plant height in the fertilizer within seed row treatment was numerically higher than the fertilizer broadcast and fertilizer next to seed row treatments in the fifth, seventh and ninth weeks. The only exception was in the third week, in which the fertilizer broadcast treatment had a higher numerical plant height than the fertilizer next to seed row and fertilizer within seed row treatments (Figure 2)

Statistically, there was a significant difference between the treatments in weeks three and seven. In the third week, there was a significant difference between the fertilizer broadcast and fertilizer within seed row treatment. There was also a significant difference between fertilizer next to seed row and fertilizer broadcast treatments. The fertilizer broadcast treatment was significantly higher than the other two treatments. (Table 6)

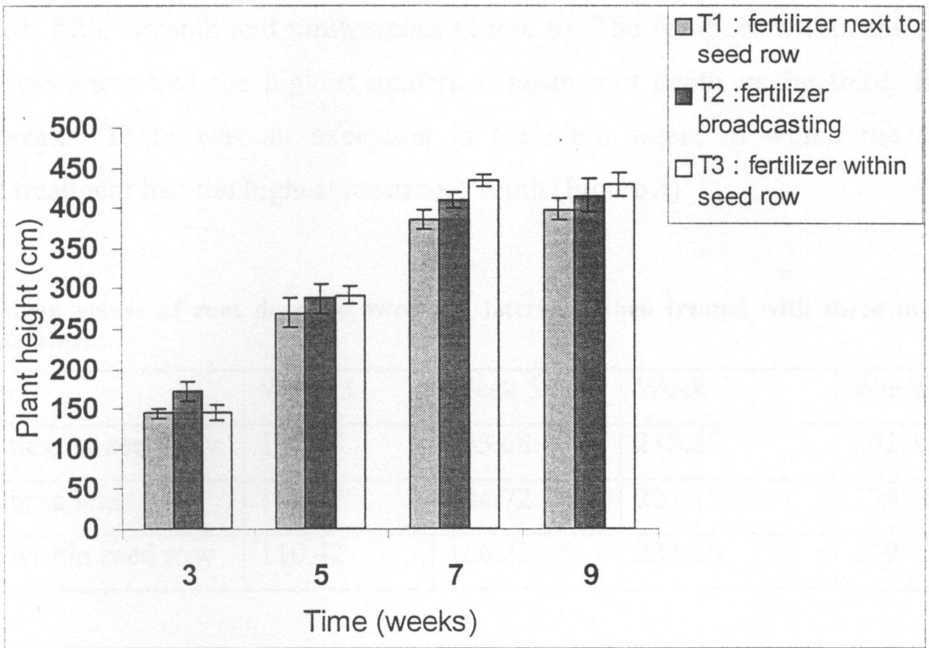

Figure 2: Plant height of fine beans at two-week intervals in relation to different methods of fertilizer placement

In the seventh week, there was a significant difference between fertilizer within seed row and fertilizer next to seed row treatments. There was also a significant difference between the fertilizer broadcast and fertilizer next to seed row treatments.

Table 5: Mean values of plant height of fine beans at two-week intervals when treated with three fertilizer placement methods

Treatment	Week 3	Week 5	Week 7	Week 9
Fertilizer next to seed row	144.55a	269.67	386.30a*	399.02
Fertilizer broadcast	171.92b	288	409.97b	415.32
Fertilizer within seed row	145.60a	292.27	434.12b	430.12

*Mean values followed by the same letter are not significantly different at 0.05 level of significance.

However, there was no significant difference between the fertilizer broadcast and fertilizer within seed row treatments.

4.1.3 Root depth

In the case of root depth, there was no significant difference among the treatment means in the third, fifth, seventh and ninth weeks (Table 6). The fertilizer within the fertilizer seed row treatment had the highest numerical mean root depth in the third, fifth and seventh weeks. There was an exception in the ninth week, in which the fertilizer broadcast treatment had the highest mean root depth (Figure 3)

Table 6: Mean values of root depth at two-week intervals when treated with three methods of fertilizer placement.

Treatment	Week 3	Week 5	Week 7	Week 9
Fertilizer next to seed row	100.55	143.68	218.27	202.32
Fertilizer broadcast	100.07	144.72	221.12	239.92
Fertilizer within seed row	110.42	166.22	234.20	229

Cooke (1967) suggests that placing bands of soluble phosphorus in the root zone ensures maximum contact between the root and fertilizer and minimum contact between the fertilizer and soil. Although the fertilizer applied was not phosphorus fertilizer, but a Compound fertilizer, it still helps to explain the growth pattern observed in the studies. The superior growth observed in the fertilizer within the seed row treatment was due to the maximum contact between the fertilizer and the roots.

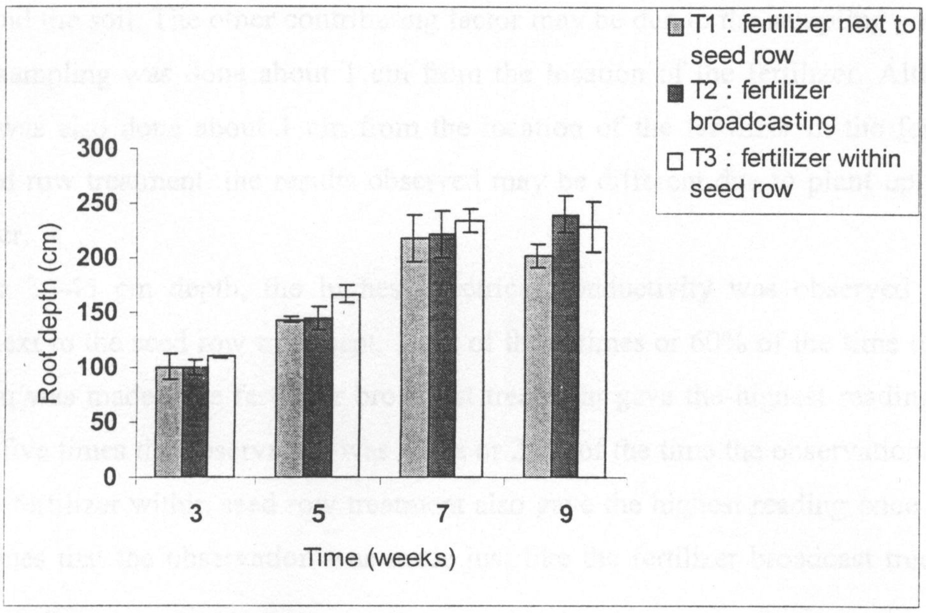

Figure 3: Root depth of fine beans at two weeks intervals in relation to three methods of fertilizer placement

4.2 Nutrient distribution

4.2.1 Electrical conductivity

The electrical conductivity for the 0-15 cm depth is shown in figure 4. The fertilizer next to seed row treatment gave the highest electrical conductivity reading in the third, fifth, eighth and tenth weeks (Figure 4). This means it gave the highest reading 80% of the time the electrical conductivity was measured. The second highest electrical conductivity was recorded in the fertilizer broadcast treatment 3 out of the 5 times that the electrical conductivity observation was done.

In the 15-30 cm depth, a similar trend was observed. The highest electrical conductivity was observed in the fertilizer next to seed row treatment 4 out of the 5 times that the electrical conductivity determination was made. The second highest reading was observed in the fertilizer broadcasting treatment and this occurred 3 times out of the 5 times that the observation of the electrical conductivity was made. In the zero week or the week before application of fertilizer, the highest electrical conductivity was observed in the fertilizer broadcast treatment for the 15-30 cm depth (Figure 5). The highest reading was observed in the fertilizer next to seed row treatment due to the fact that fertilizer banding results in a higher concentration, since there is minimum contact between the fertilizer and the soil. The other contributing factor may be due to the sampling position, since the sampling was done about 1 cm from the location of the fertilizer. Although, sampling was also done about 1 cm from the location of the fertilizer in the fertilizer within seed row treatment, the results observed may be different due to plant uptake of the fertilizer.

Within the 30-45 cm depth, the highest electrical conductivity was observed in the fertilizer next to the seed row treatment, 3 out of the 5 times or 60% of the time that the observation was made. The fertilizer broadcast treatment gave the highest reading once out of the five times the observation was made or 20% of the time the observations were made. The fertilizer within seed row treatment also gave the highest reading once out of the five times that the observation was made just like the fertilizer broadcast treatment (Figure 6)

There were no significant differences between the treatment means in the 0-15 cm depth in the zero, third, fifth and tenth weeks. Statistically, there were significant differences in the eighth week. The fertilizer within seed row treatment was significantly higher than the fertilizer broadcasting and fertilizer within seed row treatments. There were no significant difference between the fertilizer broadcast and fertilizer within seed row treatments (Table 7).

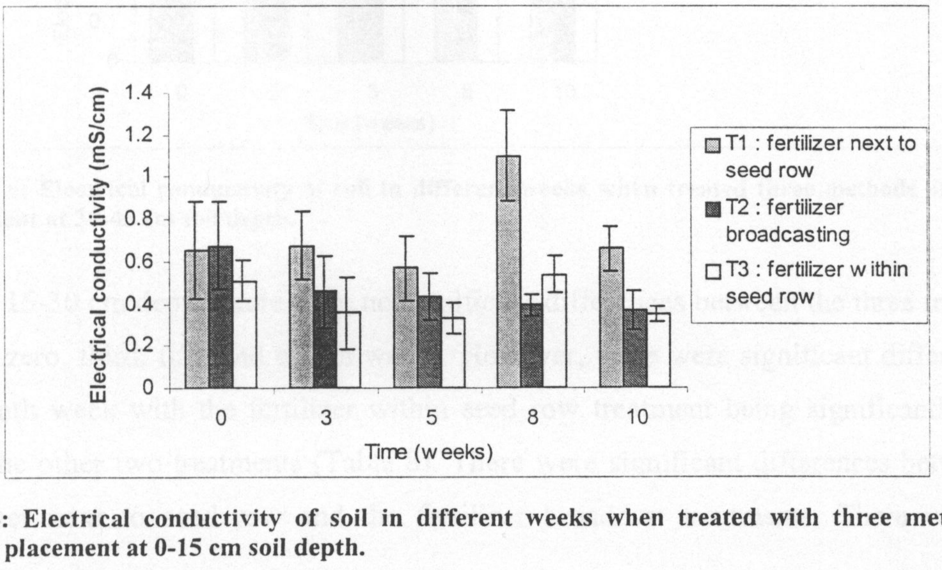

Figure 4: Electrical conductivity of soil in different weeks when treated with three methods of fertilizer placement at 0-15 cm soil depth.

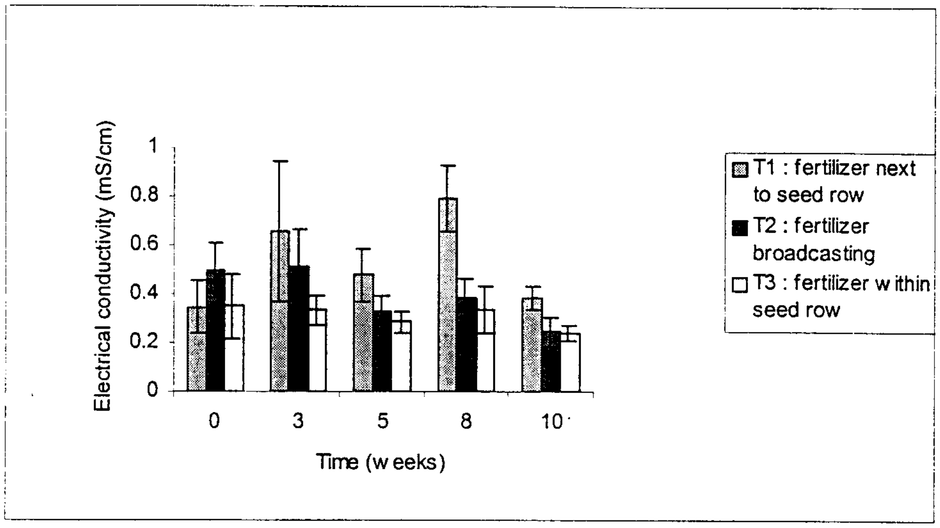

Figure 5: Electrical conductivity of soil in different weeks when treated with three methods of fertilizer placement at 15-30 cm soil depth.

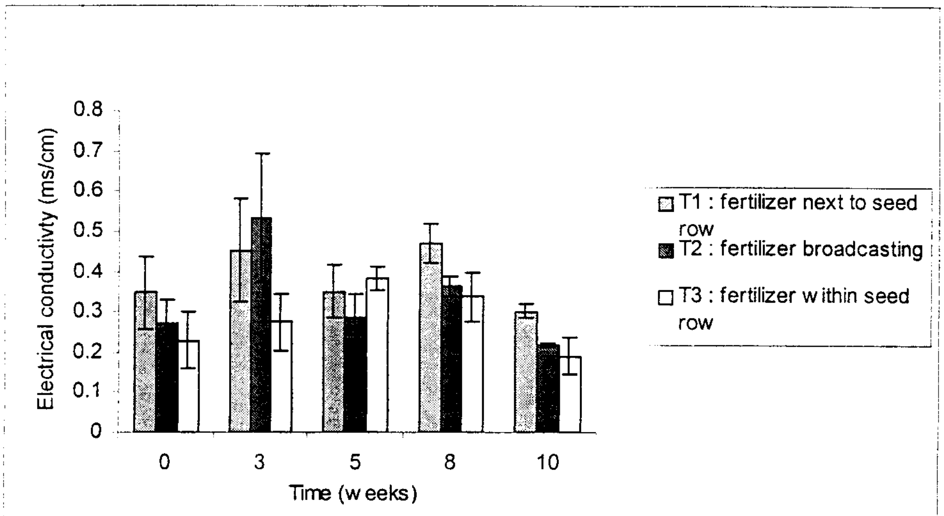

Figure 6: Electrical conductivity of soil in different weeks when treated three methods of fertilizer placement at 30-45 cm soil depth.

In the 15-30 cm depth, there were no significant differences between the three treatments in the zero, third, fifth and eighth weeks. However, there were significant differences in the tenth week with the fertilizer within seed row treatment being significantly higher than the other two treatments (Table 8). There were significant differences between the fertilizer next to seed row and the fertilizer broadcast treatments. There were also significant differences between the fertilizer next to seed row and the fertilizer within seed row treatments.

Table 7: Mean values of electrical conductivity for soil extract treated with three methods of fertilizer placement (0-15 cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	0.655	0.674	0.568	1.1a*	0.659
Fertilizer broadcast	0.676	0.456	0.432	0.394b	0.368
Fertilizer within seed row	0.511	0.358	0.332	0.538b	0.349

*Mean values followed by the same letter within the column are not significantly different at 0.05 level of significance

Table 8: Mean values of electrical conductivity of soil extract when treated with three methods of fertilizer placement (15-30cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	0.347	0.658	0.478	0.79	0.385a*
Fertilizer broadcast	0.495	0.516	0.326	0.382	0.245b
Fertilizer within seed row	0.349	0.336	0.285	0.335	0.242b

*Mean values followed by the same letter within a column are not different at 0.05 level of significance.

Table 9: Mean values of soil extract when treated with three methods of fertilizer placement (30-45cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	0.347	0.453	0.35	0.47	0.303a*
Fertilizer broadcast	0.27	0.531	0.288	0.365	0.219b
Fertilizer within seed row	0.229	0.275	0.384	0.338	0.191b

*Mean values followed by the same letter are not significantly different at 0.05 level of significance.

Within the 30-45 cm depth, there were only significant differences in the tenth week. The fertilizer next to seed row was significantly higher, than the other two treatments (Table

9). There were no significant differences between the fertilizer broadcast and fertilizer within seed row treatments.

4.2.2 Nitrate Nitrogen

There were alternate increases and decreases that occurred in the nitrate nitrogen concentration in the soil. The highest concentration was observed twice out of the five times that the determination was made in the 0-15 cm depth for the fertilizer next to the seed row treatment (Figure 7). The highest nitrate nitrogen concentration was observed once in the fertilizer broadcast treatment in the zero week. In the third week, the highest nitrate nitrogen concentration was observed in the fertilizer within seed row treatment (Figure 7). In the tenth week, the highest nitrate concentration was observed in both the fertilizer next to seed row and fertilizer within seed row treatments. From these results there was no general trend.

In the 15-30 cm depth, the highest concentration was observed in the fertilizer next to seed row treatment, three times out of the five times that the determination was made. The fertilizer broadcast treatment gave the highest nitrate nitrogen concentration, twice out of the five times that the nitrate nitrogen determination was done (Figure 8)

The fertilizer broadcast treatment gave a numerically higher nitrate nitrogen concentration than the other two treatments in the 30-45 cm depth, three times out of the five times that the observation was done. The fertilizer next to seed row treatment had the highest nitrate nitrogen concentration in the fifth week. In the eighth week, both the fertilizer broadcast and fertilizer within seed row had the highest nitrate nitrogen concentration (Figure 9)

Table 10 shows the mean values of the nitrate nitrogen concentration for all the weeks. From the table, it can be observed that there were no significant differences between the treatment means in the zero, third, eighth and tenth weeks. However, there were significant differences in the fifth week, with the fertilizer next to seed row being significantly different from the fertilizer broadcast treatment. The fertilizer within seed row treatment was also significantly different from the fertilizer broadcast treatment. No significant differences were observed between the fertilizer next to seed row and fertilizer within seed row treatment.

In the 15-30 cm depth, there were no significant differences among all the treatment means in all the weeks (Table 11)

Table 10: Mean values of nitrate nitrogen concentration of soil treated with three fertilizer placement methods (0-15cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	23.63	30.63	24.5a*	47.25	24.5
Fertilizer broadcast	25.38	24.63	14.88b	27.13	21
Fertilizer within seed row	20.12	35	22.75ac	22.75	24.5

*Mean values followed by the same letter within column are not significantly different at 0.05 level of significance.

Table 11: Mean values of nitrate nitrogen concentration of soil treated with three fertilizer placement methods (15-30 cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	14.87	30.63	24.75	23.63	15.75
Fertilizer broadcast	24.5	25.38	28	15.75	14
Fertilizer within seed row	21	23.63	19.25	22.75	12.25

Within the 30-45 cm depth, there were significant differences in the fifth week. The fertilizer next to seed row treatment was significantly higher then both the fertilizer broadcast and fertilizer within seed row treatments. There were no significant differences between the fertilizer broadcast and fertilizer within seed row treatments (Table 12)

Table 12: Mean values of nitrate nitrogen of soil extract treated with three methods of fertilizer placement (30-45cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	18.38	18.38	26.25a*	12.25	7.88
Fertilizer broadcast	20.12	24.63	19.25b	14.88	10.5
Fertilizer within seed row	14.88	13.13	14b	14.88	6.13

*Mean values followed by the same letter are not significantly different at 0.05 level of significance.

In the fertilizer next to seed row treatment, the highest amount was found in the 0-15cm depth 3 out of the 5 times that the soil was determined for nitrate nitrogen. The highest amount was found once out the five times for both the 15-30 cm and 30-45 cm depths. Similar results were observed in both the fertilizer broadcast and fertilizer within seed row treatments. Regardless of the fertilizer placement method the nitrate nitrogen is retained within the surface 0-15 cm depth. This is similar to results obtained by Ludwick and et al (1977) who studied nitrate distribution. The found that nitrate content was highest in the surface 30 cm and decreased with depth. Results by Drouineau (1969) showed that the maximum concentration of mineral nitrogen is found in the 15- 30 cm depth in the basin, which is different from the results observed in our study. This may be due to the fact that the growing of fine beans was on beds instead of basins.

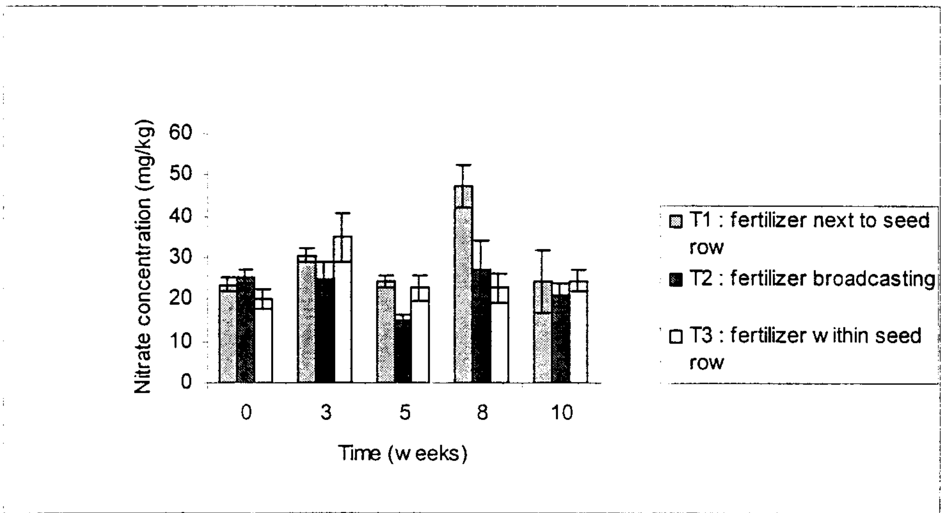

Figure 7: Nitrate nitrogen concentration of soil in different weeks when treated with three methods of fertilizer placement at 0-15 cm soil depth.

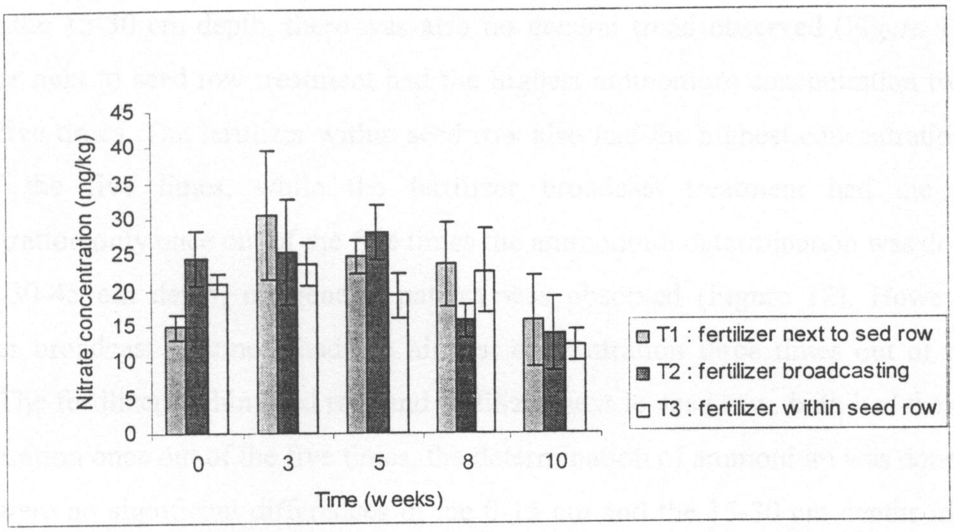

Figure 8: Nitrate nitrogen concentration of soil in different weeks when treated with three methods of fertilizer placement at 15-30 cm soil depth.

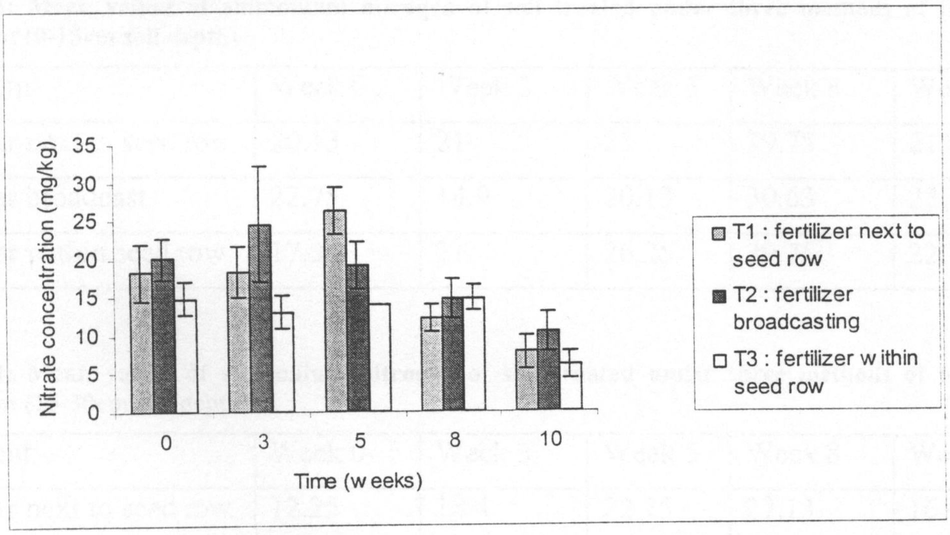

Figure 9: Nitrate nitrogen concentration of soil in different weeks when treated with three methods of fertilizer placement at 30-45 cm soil depth.

4.2.3 Ammonium nitrogen

Figure 10 shows the mean values of ammonium nitrogen in different weeks for the 0-15 cm depth. There was no general trend as can be observed from figure 10. The fertilizer broadcast treatment had the highest amount two times out of the five times that the determination of ammonium was done. The fertilizer within seed row had the highest amount only once out of the five times that determination of ammonium nitrogen was done.

Within the 15-30 cm depth, there was also no general trend observed (Figure 11). The fertilizer next to seed row treatment had the highest ammonium concentration twice out of the five times. The fertilizer within seed row also had the highest concentration twice out of the five times, while the fertilizer broadcast treatment had the highest concentration only once out of the five times the ammonium determination was done.

In the 30-45 cm depth, no general pattern was observed (Figure 12). However, the fertilizer broadcast treatment had the highest concentration three times out of the five times. The fertilizer within seed row and fertilizer next to seed row, both had the highest concentration once out of the five times, the determination of ammonium was done.

There were no significant differences in the 0-15 cm and the 15-30 cm depths in all the weeks that the determination of ammonium was done (Tables 13 and 14)

Table 13: Mean values of ammonium nitrogen of soil treated under three methods of fertilizer placement (0-15cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	20.13	21	21	29.75	21.87
Fertilizer broadcast	22.75	14.9	20.13	30.63	22.75
Fertilizer within seed row	17.5	21	26.25	29.75	22.75

Table 14: Mean values of ammonium nitrogen of soil treated under three methods of fertilizer placement (15-30cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	12.25	18.4	22.75	27.13	16.63
Fertilizer broadcast	18.38	14	21.88	23.63	15.75
Fertilizer within seed row	14	20.10	21.88	28	15.75

In the tenth week, there was a significant difference between the fertilizer next to seed row treatment and the fertilizer within seed row treatment. There was also a significant difference between the fertilizer broadcast and fertilizer within seed row treatments (Table 15)

Table 15: Mean values of ammonium nitrogen of soil under three methods of fertilizer placement (30-45cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	11.38	13.13	18.38	21	21.88a*
Fertilizer broadcast	12.25	10.5	22.75	26.25	19.25a
Fertilizer within seed row	9.63	15.75	21.88	16.63	13.12b

*Mean values followed by the same letter within a column are not significantly different at 0.05 level of significance.

In the case of ammonium, the highest concentration was observed in the 0-15 cm depth 3 out of the five times that the determination of ammonium nitrogen was done for the fertilizer next to seed row treatment. In the case of the fertilizer broadcast treatment the highest ammonium nitrogen concentration was observed in the 0-15 cm depth four out of the five times that the observation was done. In the fertilizer within seed row treatment the highest concentration was observed in the 0-15 cm depth all the times that the determination of ammonium nitrogen was done.

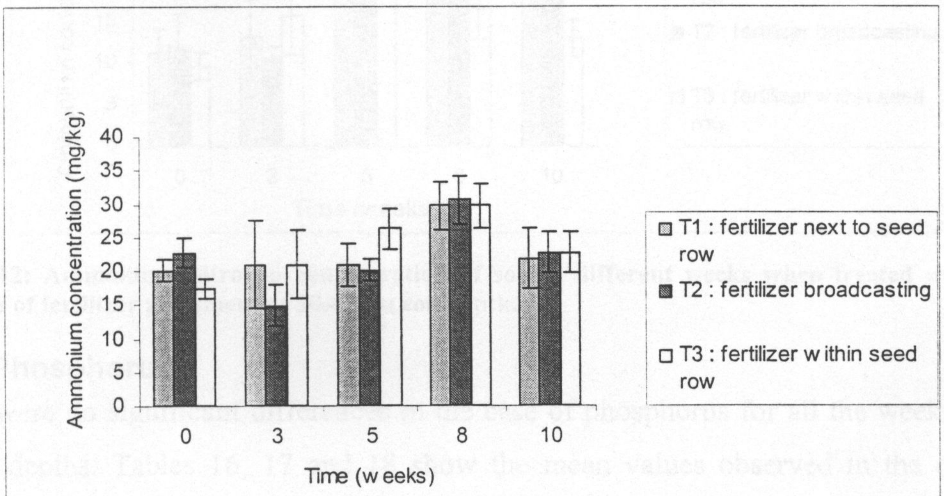

Figure 10: Ammonium nitrogen concentration of soil in different weeks when treated with three methods of fertilizer placement at 0-15 cm soil depth.

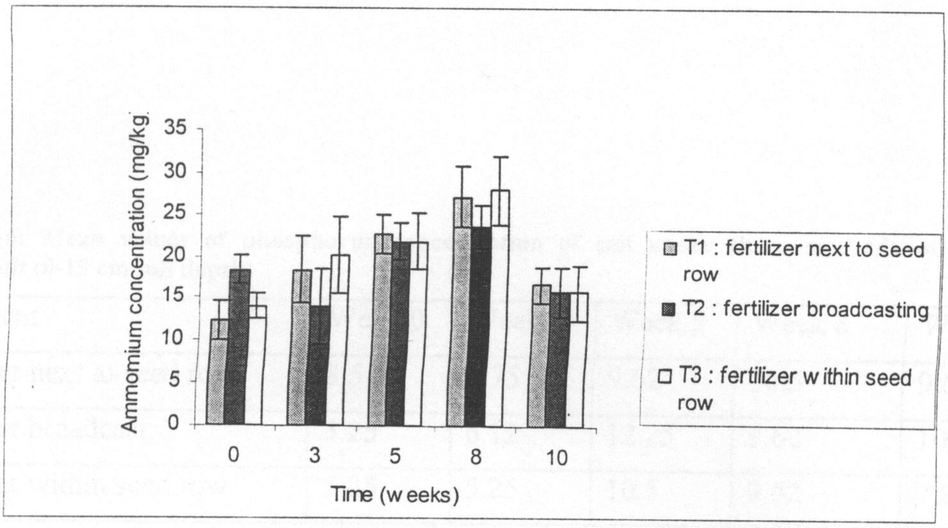

Figure 11: Ammonium nitrogen concentration of soil in different weeks when treated with three methods of fertilizer placement at 15-30 cm soil depth.

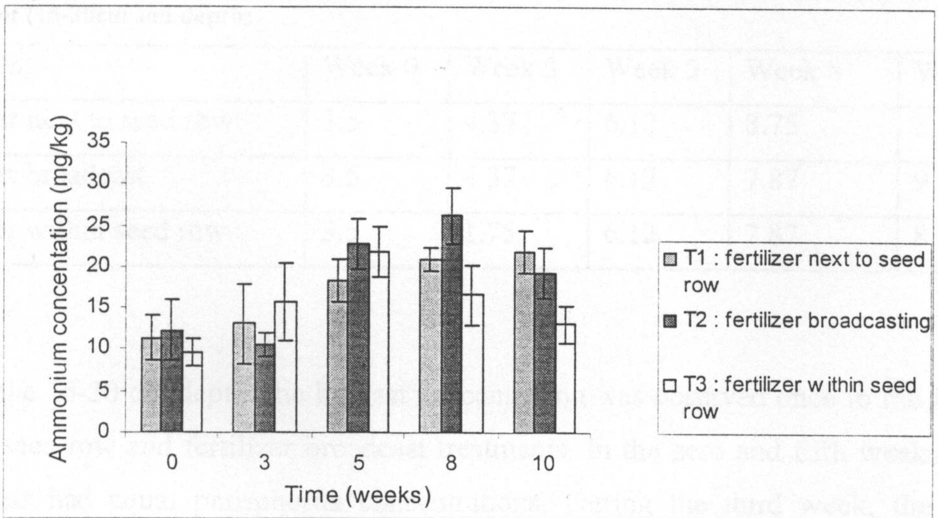

Figure 12: Ammonium nitrogen concentration of soil in different weeks when treated with three methods of fertilizer placement at 30-45 cm soil depth.

4.2.4 Phosphorus

There were no significant differences in the case of phosphorus for all the weeks and at all the depths. Tables 16, 17 and 18 show the mean values observed in the different weeks. The highest concentration for phosphorus in the 0-15 cm depth was observed twice in the fertilizer next to seed row treatment out of the five times. The fertilizer broadcast also had the highest phosphorus concentration twice like the fertilizer next to seed row treatment. The fertilizer within seed row treatment only had the highest concentration once out of the five times (Figure 13)

Table 16: Mean values of phosphorus concentration of soil under three methods of fertilizer placement (0-15 cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	3.5	8.75	9.62	10.5	9.62
Fertilizer broadcast	5.25	6.12	12.25	9.62	10.5
Fertilizer within seed row	5.25	5.25	10.5	9.62	7.87

Table 17: Mean values of phosphorus concentration of soil under three methods of fertilizer placement (15-30cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	3.5	4.37	6.12	8.75	8.75
Fertilizer broadcast	3.5	4.37	6.12	7.87	9.62
Fertilizer within seed row	3.5	1.75	6.12	7.87	8.75

Within the 15-30 cm depth, the highest concentration was observed once in the fertilizer next to seed row and fertilizer broadcast treatments. In the zero and fifth weeks, all the treatments had equal phosphorus concentrations. During the third week, the highest concentration was observed in both the fertilizer next to seed row and fertilizer broadcast treatments. From these results there was no general trend (Figure 14)

Table 18: Mean values of phosphorus concentration of soil under three methods of fertilizer placement (30-45cm soil depth)

Treatment	Week 0	Week 3	Week 5	Week 8	Week 10
Fertilizer next to seed row	1.75	1.75	1.75	7	7.87
Fertilizer broadcast	2.62	0.875	1.75	7	7
Fertilizer within seed row	0.875	0	2.62	7	6.12

In the 30-45 cm depth, the highest concentration was observed in the fertilizer next to seed row treatment twice, once in both the fertilizer within seed and fertilizer broadcast treatments (Figure 15). In the eighth week, all the treatments had the same concentration. In the fertilizer next to seed row treatment, the highest concentration was found in the 0-15 cm soil depth four out of the five times that the soil was determined for phosphorus. In the fertilizer broadcast and fertilizer within seed row treatments, the highest concentration was observed in the top 0-15 cm soil depth (Tables 16,17 and 18). These results show that phosphorus is mostly retained in the surface soil. These results are in conformity with what Drouineau (1969) found. His results showed that the greatest amount of phosphorus applied to the surface in the form of super phosphate on a calcareous clay was recovered in the top 20 cm soil depth. Though the soil depth considered was 0-15 cm, the results are similar. According to Kafkafi (1973), due to the limited mobility of phosphorus most of the phosphorus is concentrated in the plow layer, which is about 0-20 cm.

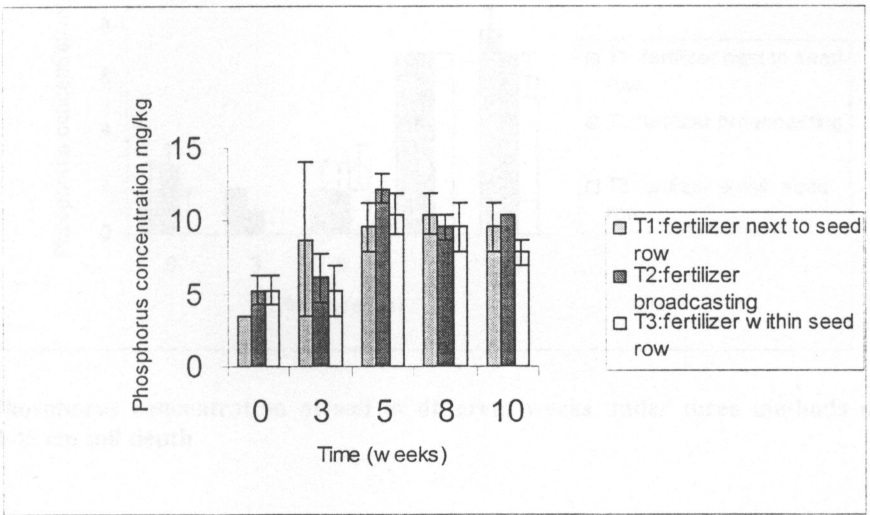

Figure 13: Phosphorus concentration of soil in different weeks under three methods of fertilizer placement at 0-15 cm soil depth.

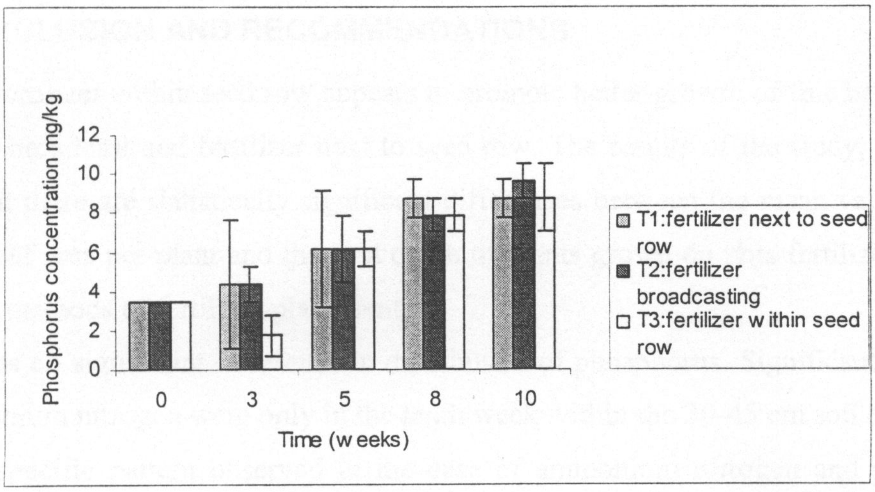

Figure 14: Phosphorus concentration of soil in different weeks under three methods of fertilizer placement at 15-30 cm soil depth.

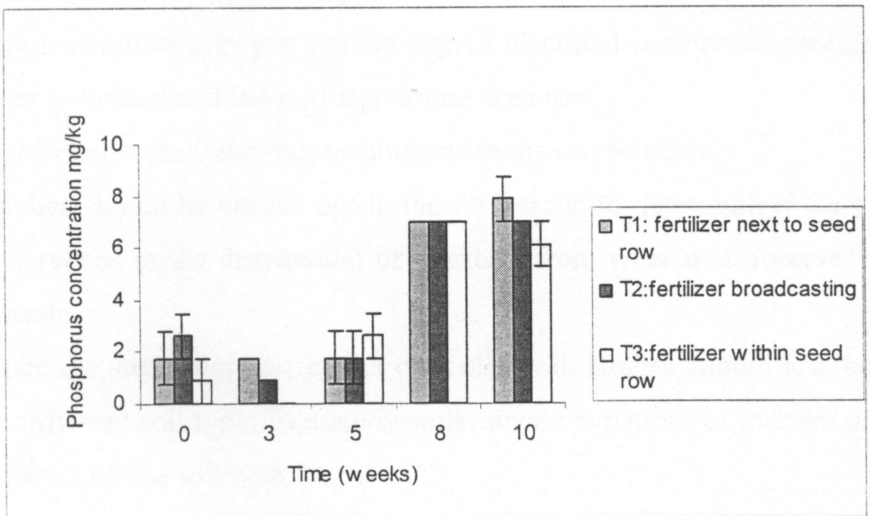

Figure 15: Phosphorus concentration of soil in different weeks under three methods of fertilizer placement 30-45 cm soil depth.

5.0 CONCLUSION AND RECOMMENDATIONS

Placing fertilizer within seed row appears to promote better growth of fine beans than the fertilizer broadcast and fertilizer next to seed row. The results of the study, however do show that there are statistically significant differences between the mean values of plant height, leaf area per plant and the root depth of plants grown on plots fertilized using the different methods of fertilizer placement.

There was no significant difference in distribution of phosphorus. Significant differences of ammonium nitrogen were only in the tenth week within the 30-45 cm soil depth. There was no specific pattern observed in the case of ammonium nitrogen and phosphorus. There were significant differences in nitrate nitrogen distribution in the fifth week within the 0-15 cm and 30-45 cm soil depth. The fertilizer next to seed row had the highest concentration of nitrate nitrogen and the highest electrical conductivity reading than both the fertilizer broadcast and the fertilizer within seed row.

Based on the results the following recommendations can be made:

1. Studies should be carried out in the dry season to determine if there will be any differences in the distribution of nutrients from what was observed in the rainy season.
2. Since the study was carried out on a clay soil, studies should also be carried out on different soil types like sandy soils, since the pattern of nutrient distribution is affected by the soil type.
3. In future studies, the yield should be considered since with the plant parameters considered there were no differences.

6.0 REFERENCES

Bunyolo A, Chirwa B and Muchinda M. 1995. Agro ecological and climatic conditions. In Muliokela S.W (ed). Zambia Seed Technology Handbook. Berlings: Arlov.

Chinene V.R.N. 1988. Detailed Soil Survey and Land evaluation of the University farm. Soil Survey Report No 160. Ministry of Agriculture and Water Development: Lusaka.

Cooke G.W. 1982. Fertilizing for maximum yields. 3rd ed. Collins: London.

Cooke G.W. 1967. The control of soil fertility. Crosby Lockwood: London.

Donahue R.L, Miller R.W and Shickluna J.C. 1983. Soils, An introduction to and plant growth. 5th ed. Prentice Hall: New Jersey

Drouineau G. 1969. Influence of irrigation on the distribution of fertilizer elements in the soil profile. In transition from extensive to intensive agriculture with fertilizers (proceedings of the 7th colloquium of the international potash institute held in Israel 1969)

Foth H.D. 1984. Fundamentals of Soil Science. 7th ed. John Wiley and Sons: New York.

Kafkafi U.1973. Nutrient supply to irrigated crops. In: Yaron.B, Danforr E and Vaadia Y. (eds). Arid zone irrigation (Ecological studies 5). Chapman and Hall Limited: London.

Harmsen G.W and Kolenbrander G.J.1965. Soil inorganic nitrogen. In: Clark F.E and Bartholomew W.V (eds). Soil nitrogen. American Society of Agronomy: Wisconsin.

Langer R.H.M and Hill G.D. 1982. Agricultural plants. Cambridge University Press: Cambridge.

Leo L, Karpi M and Hide J.C. 1970. Profitable soil management. 2nd ed. Prentice Hall Inc: New Jersey.

Ludwick A.E, Soltanpour P.N and Reuss J.O.1977. Nitrate distribution and variability in irrigated fields of North Eastern Colorado. Agronomy Journal Volume 69. American Society of Agronomy: Wisconsin.

Olaitan S.O and Lombin G.1983. Introduction to Tropical Soil Science. Macmillan: Hong Kong.

Philip A.B and Webb J.R.1971. Fertilizer technology and use. 2nd. Soil Science Society of America: Wisconsin.

Smith C.B, Demchak K.T and Ferretti P.A. 1990. Fertilizer placement effects on growth responses and nutrient uptake of sweet corn, snap beans, tomatoes and cabbage. Community in Soil Science and Plant analysis.

Thomas G.W. 1967. Nutrient mobility in soils. Accumulation and losses. Soil Science Society of America special publication No 4.

Tisdale L.S, Nelson W.L and Beaton J.D.1985. Soil fertility and fertilizers. 4th ed. Macmillan: New Jersey.

White R.W. 1997. Principles and Practices of Soil Science. The Soil as a Natural Resource. 3rd ed. Blackwell Science: Melbourne.

7.0 APPENDIX

Table 1: ANOVA for Electrical conductivity in week 0 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11					
Blocks	3	63252	21804	0.955	4.76	9.78
Treatments	2	51969	25984.50	1.18	5.14	10.92
Error (BT)	6	135530.31	22088			

Table 2: ANOVA for electrical conductivity in week 3 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	2.09				
Blocks	3	1.49	0.50	7.69	4.76	9.78
Treatments	2	0.21	0.105	1.62	5.14	10.92
Error (BT)	6	0.39	0.065			

Table 3: ANOVA for electrical conductivity in week 5 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0.58				
Blocks	3	0.24	0.08	2.16	4.76	9.78
Treatments	2	0.12	0.06	1.62	5.14	10.92
Error (BT)	6	0.22	0.037			

Table 4: ANOVA for electrical conductivity in week 8 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	1.84				
Blocks	3	0.10	0.033	0.323	4.76	9.78
Treatments	2	1.13	0.565	5.54	5.14	10.92
Error (BT)	6	0.613	0.102			

Table 5: ANOVA for electrical conductivity in week 10 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F -value	Required F at 5%	Required F at 1%
Total	11	0.51				
Blocks	3	0.002	0.00067	0.0149	4.76	9.78
Treatments	2	0.24	0.12	2.67	5.14	10.92
Error (BT)	6	0.268	0.045			

Table 6: ANOVA for electrical conductivity in week 0 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0.55				
Blocks	3	0.334	0.111	4.14	4.76	9.78
Treatments	2	0.055	0.0275	1.03	5.14	10.92
Error (BT)	6	0.161	0.0268			

Table 7: ANOVA for electrical conductivity in week 3 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	1.58				
Blocks	3	0.84	0.28	3.15	4.76	9.78
Treatments	2	0.205	0.103	1.16	5.14	10.92
Error (BT)	6	0.535	0.089			

Table 8: ANOVA for electrical conductivity in week 5 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0.31				
Blocks	3	0.15	0.05	4.16	4.76	9.78
Treatments	2	0.09	0.045	3.75	5.14	10.92
Error (BT)	6	0.07	0.012			

Table 9: ANOVA for electrical conductivity in week 8 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0.895				
Blocks	3	0.08	0.027	0.509	4.76	9.78
Treatments	2	0.50	0.25	4.72	5.14	10.92
Error (BT)	6	0.315	0.053			

Table 10: ANOVA for electrical conductivity in week 10 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0.14				
Blocks	3	0.065	0.022	6.29	4.76	9.78
Treatments	2	0.054	0.027	7.71	5.14	10.92
Error (BT)	6	0.021	0.0035			

Table 11: ANOVA for electrical conductivity in week 0 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0.247				
Blocks	3	0.106	0.035	1.84	4.76	9.78
Treatments	2	0.028	0.014	0.737	5.14	10.92
Error (BT)	6	0.113	0.019			

Table 12: ANOVA for electrical conductivity in week 3 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0.75				
Blocks	3	0.485	0.162	8.10	4.76	9.78
Treatments	2	0.145	0.0725	3.63	5.14	10.92
Error (BT)	6	0.12	0.02			

Table 13: ANOVA for electrical conductivity in week 5 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11				4.76	9.78
Blocks	3	0.67	0.22		5.14	10.92
Treatments	2	0.609	0.31			
Error (BT)	6					

Table 14: ANOVA for electrical conductivity in week 8 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0.125				
Blocks	3	0.03	0.01	1.33	4.76	9.78
Treatments	2	0.05	0.025	3.33	5.14	10.92
Error (BT)	6	0.045	0.0075			

Table 15: ANOVA for electrical conductivity in week 10 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5 %	Required F at 1%
Total	11	0.053				
Blocks	3	0.016	0.0053	2.94	4.76	9.78
Treatments	2	0.026	0.013	7.22	5.14	10.92
Error (BT)	6	0.011	0.0018			

Table 16: ANOVA for NO_3-N in week 0 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	866				
Blocks	3	155.5	51.83	0.459	4.76	9.78
Treatments	2	33	16.5	0.146	5.14	10.92
Error (BT)	6	677.5	112.92			

Table 17: ANOVA for NO3-N in week 3 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	874				
Blocks	3	245	81.67	1.19	4.76	9.78
Treatments	2	217.13	108.56	1.58	5.14	10.92
Error (BT)	6	411.87	68.65			

Table 18: ANOVA for NO_3-N in week 5 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	378.73				
Blocks	3	109.23	36.41	3.69	4.76	9.78
Treatments	2	210.29	105.15	10.65	5.14	10.92
Error (BT)	6	59.21	9.87			

Table 19: ANOVA for NO_3-N in week 8 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of Squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	2452.75				
Blocks	3	157.92	52.64	0.340	4.76	9.78
Treatments	2	1365.56	682.78	4.41	5.14	10.92
Error (BT)	6	929.27	154.88			

Table 20: ANOVA for NO_3-N in week 10 (0-15cm)

Sources of variation	Degrees of variation	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	866				
Blocks	3	155.5	51.83	0.459	4.76	9.78
Treatments	2	33	16.5	0.146	5.14	10.92
Error (BT)	6	677.5	112.92			

Table 21: ANOVA for NO_3-N in week 0 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	419.75				
Blocks	3	76.75	25.58	1	4.76	9.78
Treatments	2	190.06	95.03	3.73	5.14	10.92
Error (BT)	6	152.94	25.59			

Table 22: ANOVA for NO_3-N in week 3 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	1824.75				
Blocks	3	820.25	273.42	1.83	4.76	9.78
Treatments	2	106.69	53.34	0.356	5.14	10.92
Error (BT)	6	897.81	149.64			

Table 23: ANOVA for NO_3-N in week 5 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	596.5				
Blocks	3	139.17	46.39	1.37	4.76	9.78
Treatments	2	253.50	126.75	3.73	5.14	10.92
Error (BT)	6	203.83	33.97			

Table 24: ANOVA for NO_3-N in week 8 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	1015.75				
Blocks	3	395.08	131.69	1.03	4.76	9.78
Treatments	2	149.06	74.53	0.581	5.14	10.92
Error (BT)	6	769.73	128.29			

Table 25: ANOVA for NO_3-N in week 10 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	906.5				
Blocks	3	661.5	220.5	6.00	4.76	9.78
Treatments	2	24.5	12.25	0.332	5.14	10.92
Error (BT)	6	220.5	36.75			

Table 26: ANOVA for NO_3-N in week 0 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	354.75				
Blocks	3	150.58	50.19	2.06	4.76	9.78
Treatments	2	57.69	28.84	1.18	5.14	10.92
Error (BT)	6	146.48	24.41			

Table 27: ANOVA for NO_3-N in week 3 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	1127.25				
Blocks	3	157.58	52.53	0.447	4.76	9.78
Treatments	2	265.19	132.59	1.13	5.14	10.92
Error (BT)	6	704.48	117.41			

Table 28: ANOVA for NO_3-N in week 5 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F value	Required F at 5%	Required F at 1%
Total	11	523				
Blocks	3	122.83	40.94	2.52	4.76	9.78
Treatments	2	302.5	151.25	9.29	5.14	10.92
Error (BT)	6	97.67	16.28			

Table 29: ANOVA for NO_3-N in week 8 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	171.5				
Blocks	3	24.5	8.17	0.318	4.76	9.78
Treatments	2	18.38	9.19	0.358	5.14	10.92
Error (BT)	6	154.14	25.69			

Table 30: ANOVA for NO_3-N in week 10 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	204.5				
Blocks	3	8.5	2.83	0.108	4.76	9.78
Treatments	2	39.13	19.56	0.748	5.14	10.92
Error (BT)	6	156.87	26.15			

Table 31: ANOVA for NH_4-N in week 0 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	174.75				
Blocks	3	60.42	20.14	2.05	4.76	9.78
Treatments	2	55.31	27.66	2.81	5.14	10.92
Error (BT)	6	59.02	9.84			

Table 32: ANOVA for NH_4-N in week 3 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	1040.25				
Blocks	3	223.58	74.53	0.624	4.76	9.78
Treatments	2	100.06	50.03	0.419	5.14	10.92
Error (BT)	6	716.61	119.44			

Table 33: ANOVA for NH_4-N in week 5 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	353.75				
Blocks	3	198.58	66.19	5.82	4.76	9.78
Treatments	2	87.31	43.66	3.86	5.14	10.92
Error (BT)	6	67.86	11.31			

Table 34: ANOVA for NH_4-N in week 8 (0-15cm)

Sources of variation	Degrees of variation	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	452.25				
Blocks	3	109.25	36.42	0.641	4.76	9.78
Treatments	2	2.06	1.03	0.018	5.14	10.92
Error (BT)	6	340.94	56.82			

Table 35: ANOVA for NH_4-N in week 10 (0-15cm)

Sources of variation	Degrees of variation	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	452.75				
Blocks	3	183.25	61.08	1.39	4.76	9.78
Treatments	2	2.56	1.28	0.029	5.14	10.92
Error (BT)	6	266.94	44.49			

Table 36: ANOVA for NH_4-N in week 0 (15-30cm)

Sources of variation	Degrees of variation	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	199.25				
Blocks	3	35.92	11.97	0.860	4.76	9.78
Treatments	2	79.81	39.91	2.87	5.14	10.92
Error (BT)	6	83.52	13.92			

Table 37: ANOVA for NH_4-N in week 3 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	784				
Blocks	3	432.83	144.28	3.19	4.76	9.78
Treatments	2	79.63	39.81	0.880	5.14	10.92
Error	6	271.54	45.26			

Table 38: ANOVA for NH_4-N in week 5 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	253.50				
Blocks	3	82	27.33	0.969	4.76	9.78
Treatments	2	2.38	1.19	0.042	5.14	10.92
Error (BT)	6	169.12	28.19			

Table 39: ANOVA for NH_4-N in week 8 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1 %
Total	11	477.50				
Blocks	3	216.17	72.06	1.98	4.76	9.78
Treatments	2	42.63	21.31	0.585	5.14	10.92
Error (BT)	6	218.70	36.45			

Table 40: ANOVA for NH_4-N in week 10 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	305.25				
Blocks	3	166.42	55.47	2.43	4.76	9.78
Treatments	2	2.06	1.03	0.045	5.14	10.92
Error (BT)	6	136.77	22.80			

Table 41: ANOVA for NH_4-N in week 0 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	349				
Blocks	3	216.5	72.16	3.66	4.76	9.78
Treatments	2	14.37	7.19	0.365	5.14	10.92
Error (BT)	6	118.13	19.69			

Table 42: ANOVA for NH_4-N in week 3 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	615.56				
Blocks	3	305.23	101.74	2.39	4.76	9.78
Treatments	2	55.12	27.56	0.648	5.14	10.92
Error (BT)	6	255.21	42.54			

Table 43: ANOVA for NH_4-N in week 5 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	343				
Blocks	3	220.5	73.5	5.54	4.76	9.78
Treatments	2	42.88	21.44	1.62	5.14	10.92
Error (BT)	6	79.62	13.27			

Table 44: ANOVA for NH_4-N in week 8 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	501.25				
Blocks	3	141.92	47.31	1.64	4.76	9.78
Treatments	2	185.81	92.91	3.21	5.14	10.92
Error (BT)	6	173.52	28.92			

Table 45: ANOVA for NH_4-N in week 10 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	412.5				
Blocks	3	183.83	61.28	5.48	4.76	9.78
Treatments	2	161.38	80.69	7.19	5.14	10.92
Error (BT)	6	67.29	11.21			

Table 46: ANOVA for Phosphorus in week 0 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	32.67				
Blocks	3	8.17	2.72	1.00	4.76	9.78
Treatments	2	8.17	4.08	1.50	5.14	10.92
Error (BT)	6	16.33	2.72			

Table 47: ANOVA for phosphorus in week 3 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	427.75				
Blocks	3	76.58	25.53	0.472	4.76	9.78
Treatments	2	26.56	13.28	0.245	5.14	10.92
Error (BT)	6	324.61	54.10			

Table 48: ANOVA for phosphorus in week 5 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	85.25				
Blocks	3	36.25	12.08	2.12	4.76	9.78
Treatments	2	14.81	7.41	1.30	5.14	10.92
Error (BT)	6	34.19	5.70			

Table 49: ANOVA for phosphorus in week 8 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	69.42				
Blocks	3	4.09	1.36	0.129	4.76	9.78
Treatments	2	2.04	1.02	0.097	5.14	10.92
Error (BT)	6	63.29	10.55			

Table 50: ANOVA for Phosphorus in week 10 (0-15cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	57.17				
Blocks	3	8.17	2.72	0.470	4.76	9.78
Treatments	2	14.29	7.14	1.23	5.14	10.92
Error	6	34.71	5.78			

Table 51: ANOVA for phosphorus in week 0 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0				
Blocks	3	0	0	0	4.76	9.78
Treatments	2	0	0	0	5.14	10.92
Error	6	0	0			

Table 52: ANOVA for phosphorus in week 3 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	171.50				
Blocks	3	57.17	19.05	1.19	4.76	9.78
Treatments	2	18.37	9.19	0.57	5.14	10.92
Error (BT)	6	95.96	15.99			

Table 53: ANOVA for phosphorus in week 8 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	32.67				
Blocks	3	8.17	2.72	0.727	4.76	9.78
Treatments	2	2.04	1.02	0.273	5.14	10.92
Error (BT)	6	22.46	3.74			

Table 54: ANOVA for phosphorus in week 10 (15-30cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	60.23				
Blocks	3	27.56	9.19	1.80	4.76	9.78
Treatments	2	2.04	1.02	0.200	5.14	10.92
Error	6	30.63	5.10			

Table 55: ANOVA for phosphorus in week 0 (30-45cm)

Sources of variation	Degrees of freedoms	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	36.75				
Blocks	3	4.08	1.36	0.308	4.76	9.78
Treatments	2	6.12	3.06	0.692	5.14	10.92
Error	6	26.55	4.42			

Table 56: ANOVA for phosphorus in week 3 (30-45cm)

Sources of variation	Degrees of freedoms	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	27.56				
Blocks	3	3.06	1.02	0.333	4.76	9.78
Treatments	2	6.12	3.06	1.00	5.14	10.92
Error	6	18.38	3.06			

Table 57: ANOVA for phosphorus in week 5 (30-45cm)

Sources of variation	Degrees of freedoms	Sum of squares	Mean of squares	Calculated F- value	Required F at 5%	Required F at 1%
Total	11	35.73				
Blocks	3	3.06	1.53	0.30	4.76	9.78
Treatments	2	2.04	1.02	0.20	5.14	10.92
Error (BT)	6	30.63	5.10			

Table 58: ANOVA for phosphorus in week 8 (30-45cm)

Sources of variation	Degrees of freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	0				
Blocks	3	0	0	0	4.76	9.78
Treatments	2	0	0	0	5.14	10.92
Error (BT)	6	0	0			

Table 59: ANOVA for phosphorus in week 10 (30-45cm)

Sources of variation	Degrees f freedom	Sum of squares	Mean of squares	Calculated F-value	Required F at 5%	Required F at 1%
Total	11	24.5				
Blocks	3	8.17	2.72	1.60	4.76	9.78
Treatments	2	6.12	3.06	1.80	5.14	10.92
Error (BT)	6	10.21	1.70			